TES Observations of HDO and H_2O

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Background on Water Isotopes

Water isotopes are a good tracer for the origin, condensation, and evaporation history of an air parcel

Lighter isotopes preferentially evaporate

Heavier isotopes preferentially condense (More condensation leads to more depletion)

Isotopic composition of water vapor over the ocean is a well known function of temperature.

Reference for water isotopes is the Standard Mean Ocean Water (SMOW) = 3.1×10^{-4} HDO/H_2O

$$\delta D = 1000\left(\frac{HDO}{H_2O} / SMOW - 1\right)$$

10% depleted = -100‰

100% depleted = -1000‰

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δD of tropospheric water vapor varies from approximately -79 (above ocean) to -800 in upper troposphere.

Previous Measurements of Water Isotopes

- Global measurements of the isotopic composition of precipitation since the mid 1900's have been used to better understand surface and boundary layer hydrology (e.g., Dansgaard, Tellus, 1964; Araguas-Araguas and Froehlich, JGR, 1998)
- However these precipitation measurements do not necessarily reflect cloud processes because of the tendency of rain-drops to equilibrate to the isotopic composition of the background vapor as the raindrops fall and therefore losing the isotopic signature of the cloud! (Friedman et al., JGR, 1962)

- Useful to measure the isotopic composition of both vapor and condensate!

- Very few observations of the isotopic composition of water vapor exist!
    - Balloon (FIRS), satellite (ATMOS, ACE) and in situ measurements (ALIAS and Harvard) of isotopic composition of water vapor are used to better understand processes and sources controlling humidity in the upper troposphere and lower stratosphere
    - Boundary layer observations of HDO, $H_2{}^{18}O$, H_2O (e.g., Lawrence et al., 2004) used to characterize dynamics, precipitation, and evaporation processes of tropical storms

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Retrieval Approach

- Simultaneous retrieval of HDO and H_2O reduces systematic errors of the estimated HDO/H_2O ratio (*Worden et al., JGR, submitted*)
- Keep *a priori* and initial guess for the HDO/H_2O ratio fixed over whole globe so as to better examine spatial variability

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Greatest sensitivity to tropospheric HDO/H_2O ratio at 750 hPa

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Random error increases as surface temperature (or signal-to-noise) decreases

Random error sufficient to capture regional and global variations of HDO/H_2O ratio

Sensitivity of retrieval to the tropospheric HDO/H_2O ratio decreases with surface temperature (or signal-to-noise)

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1) “Latitude effect” We observe more depletion with increasing latitude due to gradual rainout of heavier isotopes as air moves pole-ward
2) “Continent Effect”
    - Precipitation Measurement ==> More depleted over continents relative to ocean
    - TES Vapor Measurements ==> No obvious continent effect
    - Evapo-Transpiration source larger than expected?

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TES and WB-57 ALIAS observations show similar distributions that lie within condensation and evaporation end-member models

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- Global Distribution of tropospheric water vapor is well described by combination of evaporation from ocean and condensation
- Observations below condensation models and above evaporation models require additional water source terms or processes to explain and will be discussed at the AGU

Summary

- TES retrievals of HDO/H2O ratio are most sensitive to air-mass at 750 hPa.
- Random errors of retrievals range from 10 ‰ to 25 ‰ which is sufficient for capturing regional and global variations
- TES retrievals have been compared to WB-57 ALIAS in situ measurements and the observed distributions are consistent

Results

- We observe the “latitude effect” which is due to gradual rain-out of heavier isotopes
- We do not observe significantly depleted vapor over the continents in contrast to precipitation measurements
- Global distribution of tropospheric water vapor well described by evaporation and condensation
- More science to come and shown at the AGU!